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BIOCHEMICAL STUDIES ON NUTRITION UNDER SPECIAL ENVIRONMENT

II. THE EFFECT OF REDUCED PRESSURE UPON DIGESTIBILITY*

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On repeating the exposure to reduced pressure, the metabolism of living organisms is subjected to remarkable changes in many respects. In addition to vitamins and caloric sources, the body protein will be consumed to a great extent. In order to maintain the normal nutrition under such environment, it might be important to have an adequate supply of protein. The efficient supply of protein will depend largely on the digestibility of protein material as well as the amount of its intake. It has not been shown whether or not the digestibility of food ingested might be changed by keeping a test animal under reduced pressure. So, by using albino rats, determinations have been made on the changes in the digestibility of various protein-component of synthetic diets by exposing the test animals to reduced pressure for two hours a day. Furthermore, the effects upon the digestibility of a nitrogenous component of easily digestible synthetic diet, after exposure to reduced pressure, have also been estimated.

1. EXPERIMENTAL METHOD

The synthetic diets used comprise three kinds as shown in Table 1. In every case, crude protein-content in the diet is adjusted

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to be 15%. The mixture of peptone and amino acids in the diet was prepared by autolyzing sardine in acidic medium at 50°C. for ten hours. The analysis of the mixture gives no protein- and metaprotein-N, 14% for proteose-N, 24.8% for peptone-N, 17.3% for subpeptone-N and 43.8% for amino-N.

Table 1. The composition of diets

Components of diet / Kind of diet	Sardine meal	Mixture of peptone and amino acid**	Mixture of vegetable oil and liver oil	Whole milk powder §	Wheat starch	Salt mixture	Yeast	B_1 concentrate (Oryzanine)	B_1 hydrochloride
Fish meal-diet	21	—	10*	—	60	3	5	2.5cc.	—
Peptone-diet No. 1	—	28	10	—	60	3	5	2.5cc.	—
Milk-diet	—	—	5†	64	23	3	5	—	20γ per each rat
Peptone-diet Nor. 1	—	28	5	—	65	3	5	—	20γ per each rat

* C.L.O. unit=7 † C.L.O. unit 14 § 3.78% total nitrogen, 8% fat, 7% moisture. **9.47% total nitrogen

The weighed amount of food was always given about 9 a.m. Daily records were kept of food consumption. The feces was collected about noon just after exposing to reduced pressure.** In order to collect feces not contaminated with urine, a sufficiently fine wire gauze was placed under the cage of the test animal. When exposing the test animal to reduced pressure, a fine wire gauze under the coarse one, on which the specimen rested, was used. The feces, after being acidified with hydrochloric acid, was dried at 70°C. and weighed. Dried food and feces were analyzed for nitrogen. The digestibility of solid matter or nitrogenous matter has been calculated by the following formula.

$$D = \frac{F-f}{F} \cdot 100 \qquad D_N = \frac{F \cdot N - f \cdot n}{F \cdot N} \cdot 100,$$

** Several preliminary experiments have shown that food ingested is ordinarily excreted after 8-9 hours under normal atmospheric pressure. It was observed, however, that after exposing to reduced pressure no excretion of feces took place for 4-6 hours, probably due to abundat excretion on sharp reduction of pressure.

where, D and D_N, digestibility of solid matter and nitrogenous matter, respectively; F and f, dried weight of food ingested and feces excreted, respectively; N and n, content of nitrogen in F and f, respectively. The determination of digestibility has always been carried out after several days of preliminary feeding and exposure to reduced pressure.

Albino rats used were from the same litter. By using the special apparatus reported in the preceeding paper, the experimental animals were exposed for two hours every day to reduced pressure of 300 mm. mercury corresponding to the altitude of 7,000 m., about 200 cc. air being supplied during the exposure. The rate of reduction of pressure was 90 mm. mercury per minute. A preliminary experiment had been carried out to find an appropriate time of exposure to reduced pressure. It was found that exposure for more than three hours gave so drastic an influence that sometimes death resulted especially at higher temperature. Daily exposure for two hours, accordingly, has been adopted.

Furthermore, it has also been examined in the preliminary experiment whether or not feces excreted on exposure to reduced pressure may show indigestive character, since an abundant amount of feces is usually excreted at the start in the reduction of pressure. Table 2 will clearly show that no difference in nitrogen-content is found between normal feces and feces excreted following exposure to reduced pressure.

Table 2. The nitrogen-content of feces on exposure to reduced pressure compared with feces under normal pressure

Kinds of feces / Date	Fish Meal-Diet Feces excreted under						Peptone-Diet Feces excreted under					
	normal pressure			reduced pressure			normal pressure			reduced pressurs		
	Dried wt.	Mois-ture	N	Dried wt.	Mois-ture	N	Dried wt.	Mois-ture	N	Dried wt.	Mois-ture	N
V/26	3.10	31.2	5.36	1.77	32.0	4.81	3.75	53.0	4.10	1.12	53.5	3.70
27	2.11	34.0	5.73	1.25	35.0	4.54	4.60	35.0	4.13	0.90	36.0	4.06
30	2.05	26.8	4.92	0.96	40.1	4.72	3.82	22.0	3.46	1.78	31.5	3.60
31	0.81	10.3	4.29	1.66	33.4	4.58	2.45	18.4	3.88	1.78	31.6	3.77
VI/ 1	2.22	17.9	4.64	1.52	34.0	4.56	2.53	18.5	3.53	1.70	32.0	3.73
2	1.52	20.1	4.67	1.87	35.5	3.96	2.14	33.2	—	1.13	24.7	—

2. Experimental Results

Results obtained by comparing the milk powder- or fish meal-diet with the peptone-diet are shown in Table 3, 4, 5, and 6. All the data are summarized in Table 7.

Table 3. Digestibility of fiish meal-diet, rate of growth, and food ingested at 28—30°C.

Date	Under Reduced Pressure						Under Normal Pressure					
	Body wt. ♀	♂	Food ingested		D		D_N		Body wt. ♀	♂	Food ingested		D		D_N	
VII/6	92	86	10.2	11.0	88.0	87.5	80.6	78.5	90	111	11.7	12.8	88.4	86.7	77.8	76.8
7	97	89	10.7	10.7	76.8	88.7	52.5	77.2	94	118	11.1	13.9	88.6	87.0	74.8	74.5
9	102	94	9.1	10.4	90.2	90.0	79.1	80.7	99	129	10.4	17.3	92.4	91.4	87.2	85.6
10	102	92	7.0	7.4	84.9	73.7	72.0	68.6	101	135	9.1	15.8	84.6	83.0	69.2	79.5
11	102	95	7.2	7.2	88.5	92.5	79.1	88.2	105	140	9.5	15.6	91.9	88.2	85.9	79.6

Table 4. Digestibility of peptone-diet, rate of growth, and food ingested at 28—30°C.

Date	Under Reduced Pressure						Under Normal Pressure					
	Body wt. ♀	♂	Food ingested		D		D_N		Body wt. ♀	♂	Food ingested		D		D_N	
VII/6	97	96	10.4	11.8	95.2	96.0	93.3	93.7	100	102	11.1	12.2	94.6	90.3	92.9	80.0
7	99	99	8.6	8.6	95.6	96.3	92.3	91.9	104	108	10.9	12.3	92.7	95.1	85.6	92.8
9	103	104	6.9	8.0	95.3	94.5	92.1	89.6	111	117	8.7	11.0	95.0	93.4	92.3	87.1
10	103	102	6.3	7.0	95.7	92.4	92.2	86.5	110	114	8.5	10.0	96.2	93.5	93.5	90.0
11	107	106	8.6	11.8	95.8	99.0	93.1	98.6	111	118	11.2	12.8	95.2	97.2	91.5	95.9

Difference of digestibility between the peptone- and the milk powder-diets was 3.6% in solid matter, and 5.7% in nitrogenous matter. When exposed to reduced pressure, the difference was greater, i.e., 6.5% in solid matter and 8.7% in nitrogenous matter. However a more pronounced difference has been observed between the peptone- and the fish meal-diets. It is a remarkable fact that peptone can be utilized 8.7% more efficiently than the protein of

Table 5. Digestibility of milk-diet, rate of growth, and food ingested.

Date	Under Reduced Pressure								Under Normal Pressure							
	Body wt.		Food ingested		D		D_N		Body wt.		Food ingested		D		D_N	
	♀	♂							♀	♂						
IX/6	79	72	6.7	6.3	86.9	86.1	81.5	80.0	72	78	7.2	7.7	84.8	86.6	81.1	81.8
7	81	73	7.2	6.6	90.3	89.9	87.2	85.3	75	81	7.2	8.4	91.1	92.6	88.3	89.6
8	85	75	9.6	7.7	91.6	91.0	87.8	86.3	76	85	8.3	9.6	92.0	93.2	88.5	89.5
9	83	73	9.3	4.9	90.5	82.6	85.5	79.0	79	87	7.5	8.9	88.0	89.2	82.8	83.3
10	89	77	8.5	6.8	88.0	—	85.4	—	81	88	8.5	8.0	92.0	89.2	88.5	85.6
11	91	79	7.4	6.8	91.0	86.5	88.5	82.8	85	92	8.0	8.5	88.9	90.4	85.0	87.5
12	94	83	8.4	8.4	91.1	88.2	88.3	82.8	89	97	9.6	9.0	93.8	93.8	90.5	91.2
13	98	86	8.0	8.0	86.6	87.7	85.3	83.8	90	99	9.1	8.5	89.2	87.9	84.0	82.5
14	99	88	7.5	8.1	86.6	85.4	84.0	81.3	94	102	9.3	9.3	90.7	91.0	85.2	86.5
15	101	90	7.3	7.3	91.5	89.4	89.0	84.1	99	107	9.1	9.7	93.4	93.3	90.1	90.4
16	103	93	8.0	8.0	85.9	86.3	83.5	81.4	101	110	10.8	9.1	89.0	89.4	84.6	85.3

Table 6. Digestibility of peptone-diet, rate of growth, and food ingested

Date	Under Reduced Pressure								Under Normal Pressure							
	Body wt.		Food ingested		D		D_N		Body wt.		Food ingested		D		D_N	
	♀	♂							♀	♂						
IX/6	73	62	9.9	10.1	93.7	90.7	91.5	88.7	66	69	11.8	7.4	93.6	94.8	91.1	93.5
7	71	65	7.2	8.1	93.6	93.0	90.0	90.0	69	75	9.6	11.0	95.5	94.1	92.8	90.5
8	74	69	8.0	7.5	94.4	93.7	92.5	92.0	70	71	9.5	3.5	93.7	—	91.1	—
9	75	69	9.1	9.1	94.0	93.8	92.2	92.1	73	69	9.5	7.3	94.9	—	93.2	—
10	79	71	9.0	7.3	93.7	96.9	91.0	95.7	75	72	9.4	8.6	95.2	95.0	93.1	92.7
11	81	74	8.0	7.1	92.7	95.8	90.9	95.3	74	76	8.8	9.7	92.7	93.3	90.2	91.9
12	86	77	9.2	8.8	94.9	96.5	93.7	95.5	80	83	9.2	10.6	90.5	91.4	87.8	89.1
13	86	79	9.2	10.7	96.0	97.4	95.3	97.2	84	88	11.6	11.6	94.6	94.6	93.3	94.0
14	90	79	13.4	10.8	95.0	98.3	94.0	97.8	87	85	15.9	14.0	94.8	96.4	93.5	95.7
15	95	81	9.4	6.7	96.5	94.1	95.5	92.7	91	92	10.7	8.9	95.0	96.1	93.9	94.7
16	98	84	9.9	8.3	92.6	93.3	91.1	91.6	94	95	9.1	9.1	94.0	91.2	92.5	88.6

milk and 16.6% more efficiently than the protein of fish meal. This result certainly favors the use of peptone as a protein-source in aviator's rations.

Table 7. Summary of the Results

	Increase in body weight per g. food				D		DN		D		DN	
	Fish meal diet	Pep-tone diet	Milk diet	Pep-tone diet	Fish meal diet	Pep tone diet	Fish meal diet	Pep-tone diet	Milk diet	Pep-tone diet	Milk diet	Pep-tone diet
Normal press.	0.33	0.25	0.32	0.25	88.2	94.5	79.2	90.3	90.6	94.2	86.5	92.2
Reduced press.	0.21	0.23	0.27	0.24	86.2	95.6	75.7	92.3	88.2	94.7	84.5	93.2
Difference	−0.12	−0.02	−0.05	−0.01	−2.0	+1.1	−3.5	+2.0	−2.4	+0.5	−2.0	+1.0

It is of particular interest to note that milk- and fish meal-diets are digested to less extent on exposure to reduced pressure, whereas the peptone-diet is digested to a somewhat greater extent. This decrease in digestibility may be accounted for by the decrease in secretion of digestive enzymes due to the effect of exposure to reduced pressure. It is also apparent that the assimilability of peptone will not be changed to any extent by the decrease in secretion of the enzymes.

It is to be pointed out that the value of increase in body weight per unit weight of peptone-diet remained almost the same on exposure to reduced pressure while the value per unit weight of milk-diet decreased by about 15%. This will also prove the efficient utilization of peptone-diet in the animal body under such drastic effect.

3. Summary

1. By exposing albino rats to reduced pressure, an appreciable decrease has been noticed in the digestibility of solid as well as the nitrogenous matter of diet containing fish meal or milk powder as protein-source.

2. No decrease, by exposing to reduced pressure, has been observed in the digestibility of diet containing a mixture of peptone and amino acids.

3. By keeping the test animal under reduced pressure for two hours daily, peptone can be utilized 8.7% more efficiently than the protein of milk and 16.6% more efficiently than the protein of fish meal.

4. These experimental findings give credence to the presumption that the secretion of digestive enzymes, especially proteolytic, may decrease in appreciable amount only by keeping the specimen under reduced pressure for two hours.

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